Oceanographic Measurement Surveys Using a Custom AUV: Mixing Induced in the Upper Mixed Layer on a Continental Shelf During Adverse Weather Conditions

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LONG-TERM GOALS

The principal long-term goal of this work is to contribute to the development of physics-based numerical models for accurate assessment and prediction of the ocean environment. Such models are required, for example, for rapid environmental assessments preceding MCM operations. Our contribution is based on developing accurate parameterization of the active small-scale processes in the water column through observations from fixed and mobile AUV platforms. The parameterizations are needed to correctly model subgrid scale processes in predictive numerical models. The aim is to develop the necessary data bank to help parameterize the sub-grid processes under various, measured background conditions.

OBJECTIVES

(i) Determine, using a custom AUV platform, the structure of the subsurface oceanic layer, including distribution of bubbles, currents, thermohaline fluxes, and rates of dissipation and mixing, together with the structure of the close-bottom boundary layer during high onshore wind events. The aim is to parameterize the physical processes induced in the subsurface layer and the bottom boundary layer by the atmospheric forcing for incorporation and validation of models of these processes. (ii) Develop a custom, dedicated surveyor AUV, for making quality oceanographic measurements for use in the proposed and future oceanographic experiments under a variety of scenarios.

APPROACH

The following tasks were identified in pursuing the objectives:

Task 1 *Development of a custom AUV* Using previous experience with the Ocean Explorer as a basis, a custom vehicle will be developed taking account of the considerations such as vibration isolation of the AUV machinery from the payload section and chatter-free control. For greater versatility, it would be desirable to increase the depth rating from 300m to a 1000m, say. Such an increase will allow future missions in the Gulf Stream and will involve modification of the pressure hull. The robustness of the vehicle and its operation to stormy conditions will also be a requirement. We will work closely with

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14. ABSTRACT

The principal long-term goal of this work is to contribute to the development of physics-based numerical models for accurate assessment and prediction of the ocean environment. Such models are required, for example, for rapid environmental assessments preceding MCM operations. Our contribution is based on developing accurate parameterization of the active small-scale processes in the water column through observations from fixed and mobile AUV platforms. The parameterizations are needed to correctly model subgrid scale processes in predictive numerical models. The aim is to develop the necessary data bank to help parameterize the sub-grid processes under various, measured background conditions.

15. SUBJECT TERMS

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the AUV development team to ensure that the necessary requirements are met and details of the navigational and positional accuracies are determined. The present Morpheous launch and recovery system will require some modification since the turbulence package will be mounted on its nose.

Task 2. *Implementation of the oceanographic measurement sensors* The sensor system on the custom AUV will include: a GPS navigation system, a compass, a motion sensor package, an upward and a downward looking 1200kHz ADCPs, two Microtech CTD packages, the microstructure turbulence package, consisting of two shear probes, 3-D electromagnetic microstructure velocity sensor and fast response conductivity and temperature sensors, a broadband (6-196kHz) bubble resonator designed by David Farmer's group, two 300Hz sidescan and one vertical look sonars, and an ARGOS communication system. The possibility of implementation of a single custom upward and downward looking ADCP, of the type mounted on the REMUS vehicle, will be explored with RDI.

Task 3. *Test of vehicle and sensor system operation.* This will be carried out in summer 2001. The mixed layer mission of July 1999 will be repeated as part of the test, extending the scope to include measurements afforded by the additional sensors and operation in high wind conditions. The object will be to make turbulence measurements and gain experience with making the bubble measurement with the new vehicle during high southeast wind conditions.

Task4. *Analysis of data acquired during fall 2000.* Analyze bubble and turbulence distribution measurements carried out during previous year.

Task 5. *Fall 2001 Experiment in high onshore wind conditions* A field experiment in fall 2001 involving an AUV survey of the upper mixed layer under high onshore wind conditions at the SFTF site is proposed.

WORK COMPLETED

Task 4 has been completed and publications are under preparation. Progress on other tasks has been delayed in view of an imposed hold on activities and funding. Task 1: Two quotes have been developed as alternatives to initial plan in view of new restrictions that resulted following loss of key FAU personnel. One of the two options will be selected after consultation with the program manager. Tasks 2, 3 and 5 will follow task 1. A limited experiment will be carried out with existing Ocean Explorer AUV during Winter 2001 using a team that is currently engaged in completing the Saclant vehicles. A no-cost extension will be requested to complete the work.
Analysis of measurements from a mixed layer mission in summer 1999 has been reported in special AOSN issue of IEEE Journal of Ocean Engineering.

RESULTS

Analysis of previous field experiments have been underway. The bubbles and the sidescan packages have been implemented (Figure 1a) and initial test measurements were made during winter, 2001. The survey path is shown in Figure 1b. Sample data from these tests are shown in Figures 1(c), 2a-c. The sensors will be used in the field experiment for measuring bubble distribution from breaking waves.

Summer 1999 mixed layer experiment This involved simultaneous AUV-based observations and synoptic surface current observations using the OSCR. The work will appear in a special issue of the IEEE Journal of Ocean Engineering (Dhanak et al, 2001). The measurements from the AUV were

used to develop maps of the distribution of temperature, salinity, density, currents and dissipation rate (Figures 3, 4). Currents measured from the AUV and a bottom mounted ADCP at 2.5m depth are compared with the OSCR surface currents in Figure 5. Other results are shown in the composite Figure 6. Full details can be found in the paper.

Spring 2000 Adverse Weather Experiment The Spring AWE experiment, off the east Florida coast, was successfully carried out in April 2000. All measurement systems functioned correctly during the passage of the front and a substantial amount of oceanographic and atmospheric data has been collected. An analysis of the field measurements is underway and full details will be available when this is complete. Sample results are given in the figures and figure captions in the annual ONR report. The front was weakened by the appearance of a warm high-pressure region off SW Florida. As a result, the drop in temperature was mitigated. 5-10m/s winds blowing offshore from the west during the AUV survey is apparent from the figure. The offshore winds did not have enough fetch to produce significant waves. However, the presence of significant wind stress is evident from the figure. Measurements from the ASIS buoy, the OSCR and the 24-hr AUV survey will be synthesized to develop an understanding of the impact of the front on water column. Sample data from the mission are shown in Figure 7.

IMPACT / APPLICATIONS

An AUV dedicated for oceanographic measurements will provide quality information about physical subsurface processes, over a range of scales, which underlie synoptic scale observations such as from a satellite or a surface current radar.

TRANSITIONS

Collaboration with University of Miami, University of Victoria, Canada, and Institute of Ocean Sciences, Canada are continuing. The turbulence and bubble measurement package is being extended to include sensors for measurement of dissolved oxygen and chlorophyll in the water column. Participation in an ONR funded ocean acoustic experiment has been proposed and proposals are being written to NSF and NOAA for application of the dedicated AUV in longer term oceanographic experiments.

RELATED PROJECTS

The work is carried out in conjunction with N00014-00-1-0218 and other ONR-322OM/AOSN projects funded at Florida Atlantic University.

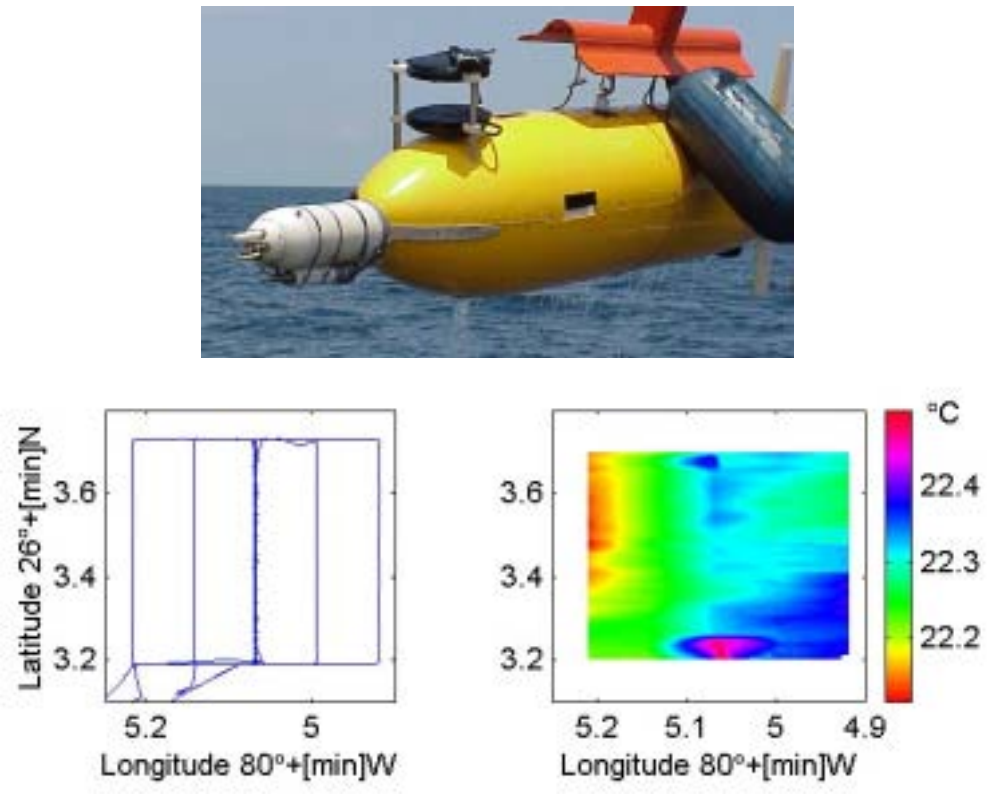

Figure 1 (a)(top) OEX AUV and sensor systems during recovery, (b) (bottom left) AUV survey path, (c) (bottom right) Inferred temperature field

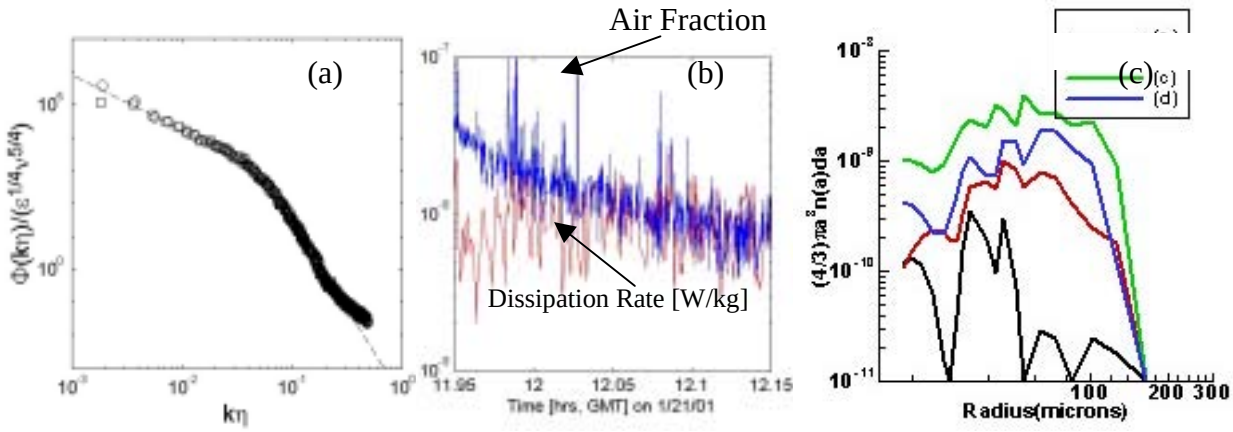

Figure 2 (a) Velocity Spectra, (b) Air fraction and Dissipation rate, (c) Bubble size distribution at various times

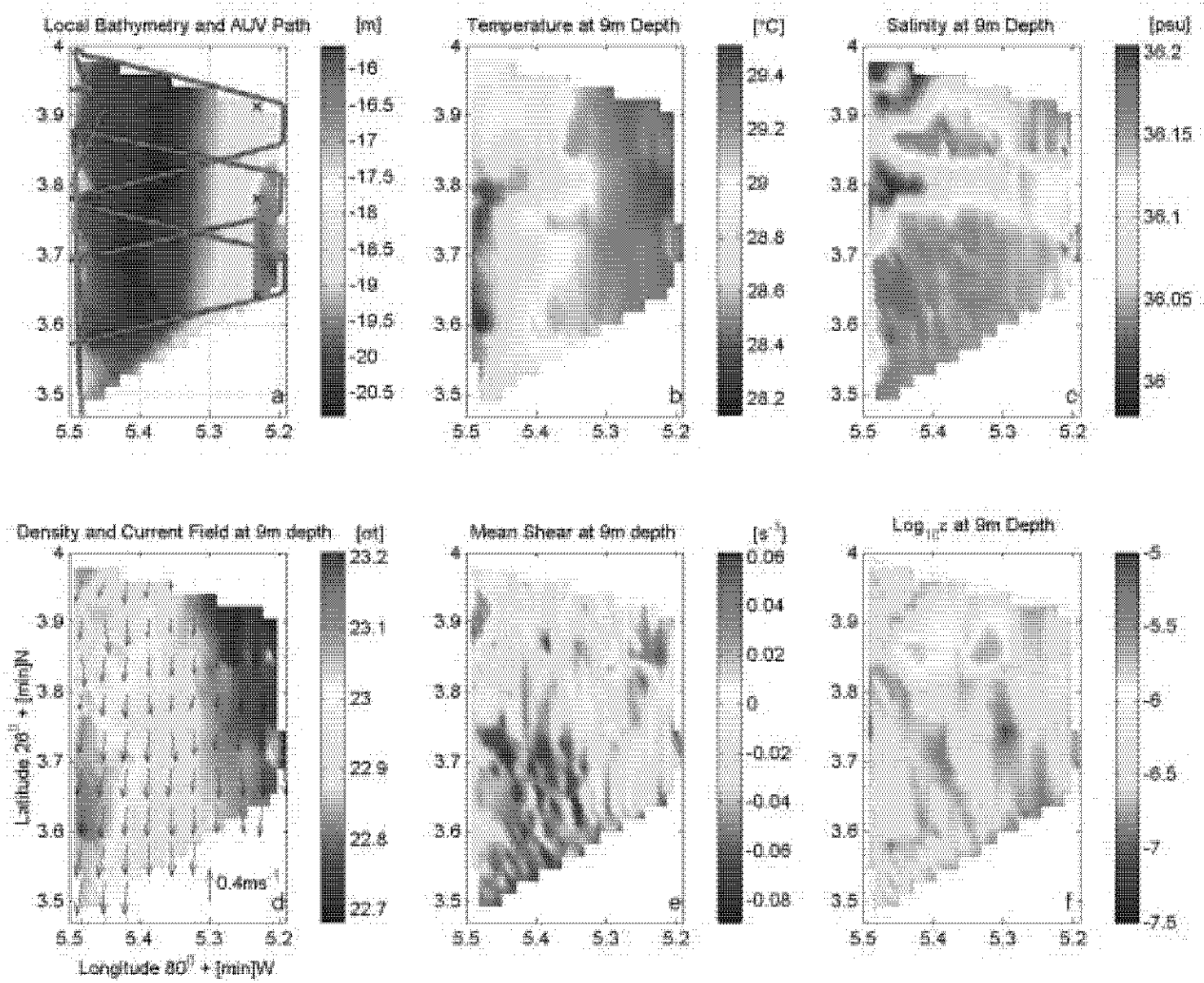

Figure 3a-f. Observations from the second segment of the continuous 12-hour AUV survey off the coast of south Florida on 7/27/99. The survey segment shown was carried out during 1524-1646 GMT and the maps have been developed through spatial interpolation of data acquired during this time.

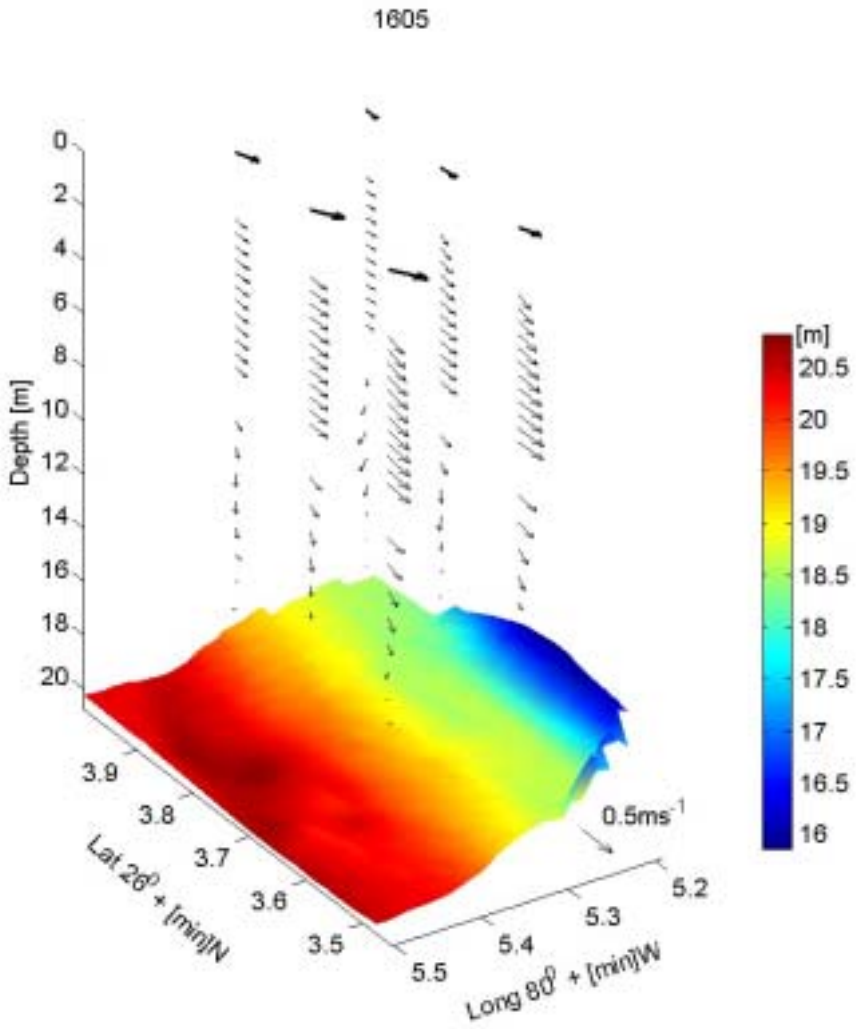

Figure 4 Current profile of the low-pass filtered (at 15 minutes) current-field at the six OSCR grid points as determined from the AUV survey during the second segment of the survey. The surface current vectors recorded by OSCR (thicker arrows) are overlaid.
The colors indicate the local water depth

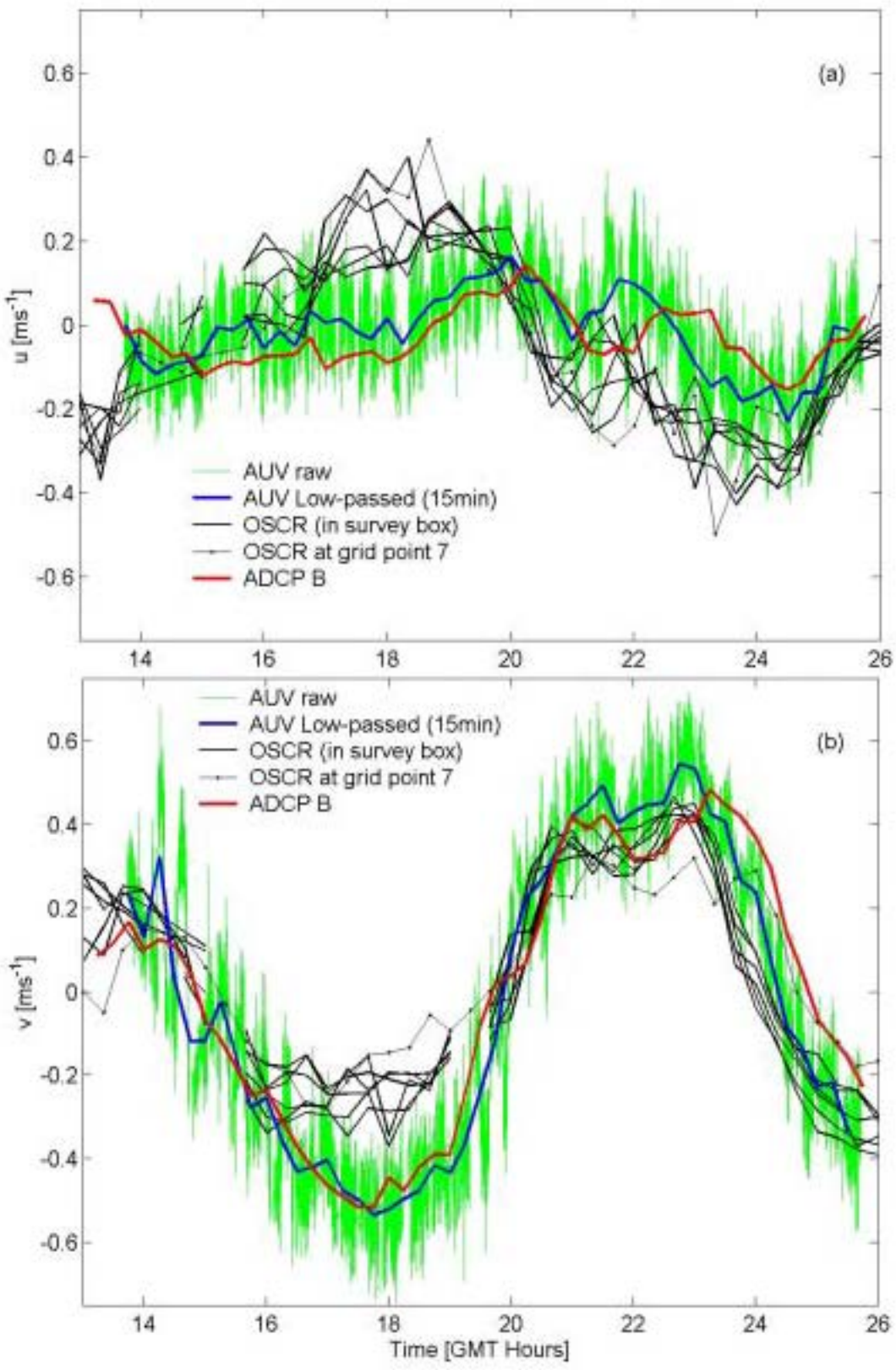

Figure 5 Time series of (a) u and (b) v at 2.5m depth from the AUV and ADCP B records and surface currents from OSCR at the six grid points in the survey box and at grid point 7. The blue line is the AUV data, low-pass filtered at 15 minutes.

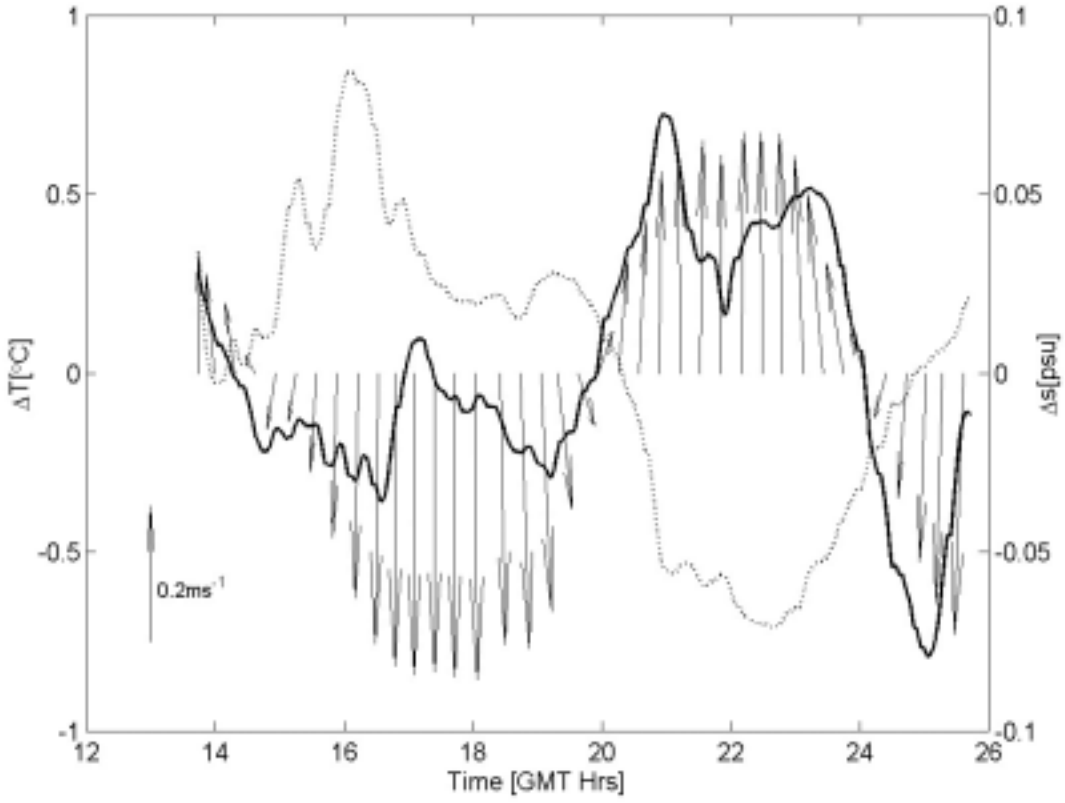

Figure 6. An overlay of current vector field at 9m depth, temperature variation, T, (thick line), and salinity variation, s, (dotted line) as determined from the AUV measurements. Each time series has been low-pass filtered at 15 minutes.

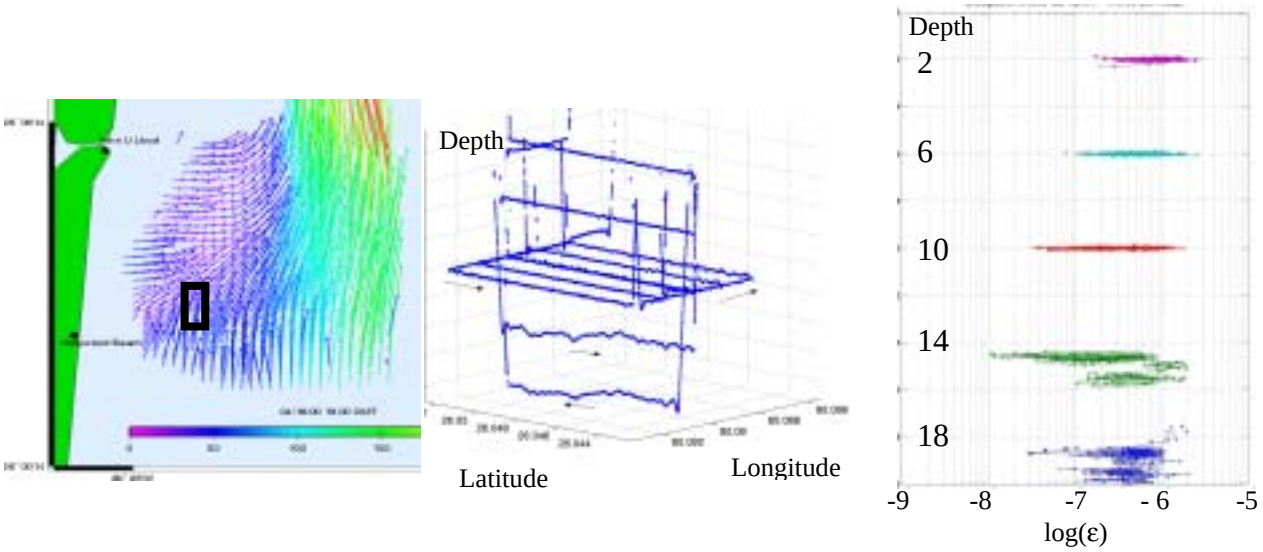

Figure 7(a) Surface current distribution and AUV survey box, (b) AUV mission path. (c) Distribution of rate of dissipation with depth

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(2) *An AUV Survey in the Littoral Zone: Small-scale Subsurface Variability Accompanying Synoptic Observations of Surface Currents*. Manhar R Dhanak, Edgar An, and Ken Holappa.. To appear in IEEE Journal of Ocean Engineering.

(3) *An AUV for benthic boundary layer turbulence measurements*. K Holappa and M. R. Dhanak. To appear in IEEE Journal of Ocean Engineering.

(4) *Measurement of the Concentration and Size Distributions of Bubbles in the Upper Mixed Layer Using an AUV*. M R Dhanak, M Chernys, K Holappa, E Leindecker, D. Farmer and S. Vagle. Oceanology International 2001. Miami Fl, April 2001. Full Paper

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